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COMBINED REPORT
Site Characterization
Remedial Investigation
Risk Assessment
Cleanup Plan
Phillips Island
Marcus Hook Refinery
Marcus Hook, Pennsylvania

Prepared for:

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2.0 BACKGROUND

The following information presents a summary of the physical features at the site, the site history, the current state of remedial actions, and planned future use. The information is based on the approach presented in the PADEP Land Recycling Program Technical Guidance Manual, specifically:

- Site reconnaissance
- Review of the facility files at the Sunoco Marcus Hook refinery
- Pennsylvania Department of Environmental Protection (DEP) files
- United States Environmental Protection Agency (USEPA) files
- Phase I Environmental Site Assessment (Phase I ESA) completed by URS/Dames & Moore in November, 1999

2.1 SITE LOCATION

The Phillips Island site is located in the southwest section of the Sunoco Marcus Hook refinery. The address of the refinery is Delaware Avenue and Green Street in Marcus Hook, Delaware County, Pennsylvania. Figure 1 is a site location map.

2.2 SITE DESCRIPTION

Phillips Island (the Island) is an area of approximately 27 acres, 21.1 acres of which FPL Energy Marcus Hook, L.P. (FPLE) is considering for occupation. The "Island" in this report is restricted to those 21.1 acres. The Pennsylvania and Delaware state border passes through the site. Of the 21.1 acres, approximately 4 acres are located in Delaware.

The Island extends north to stormwater aboveground storage tank (AST) T-101, a PECO electrical substation, and wastewater AST TK-131, south to the Delaware River, west to the Ethylene Complex and east to Blueball Avenue. Currently, the Island resembles a small peninsula. In the past, the Island was detached from the main shoreline. The channel separating the island from the shore was gradually filled.

The Island surface is covered by gravel with some minor grass covered areas. The surface is relatively flat with minor surface topographic expressions and a raised fill area to the south. Along the southern property boundary, the Island slopes steeply to the Delaware River. The slope is covered with concrete riprap to prevent erosion. The slope is terraced to accommodate an access road that surrounds the southern perimeter of the Island. There are seven monitoring and light non-aqueous phase liquid (LNAPL) recovery wells around the Island perimeter.

Existing surface features include two ASTs, a roll-off container staging area, a fire-fighting training area, and a sandblasting area. Figure 2 is a site layout showing the pertinent features of the Island.

The ASTs include a 1,000-gallon propane AST and a 500-gallon AST for containing LNAPL recovered from wells. Based on the files at the refinery, there is no history of releases from these ASTs nor was staining observed in their vicinity during the Phase I ESA.

The roll-off container staging area is used to store empty containers and stage full containers for shipment off-site. The staging area is unpaved; minor soil staining was observed during the Phase I ESA. The roll-off staging area has been in operation since 1970.

The fire-fighting training area (the Training Area) includes a tanker truck and two open-top ASTs. The ground surface is concrete-paved and gravel. The training exercises involve placing a small amount of oil on a layer of water in the tanker truck and ASTs and igniting the oil. The Training Area was constructed in 1996. Before 1996, the Training Area was located near the present location of the substation immediately north of the Island. During the Phase I ESA, URS/Dames & Moore observed minor staining on the ground surface.

2.3 SITE HISTORY

The following paragraphs describe the site history of Phillips Island. The information presented is based on a site history summarized in an internal Sun memorandum, dated January 13, 1992.

Up until the 1930's, the Island was part of a quarantine station for ships steaming up the Delaware River into Philadelphia. Between the 1930's and the early 1940's, the Island was owned by the Phillips family. Sunoco first came into possession of the Island in the 1940's when Sunoco purchased it from the Phillips. Shortly thereafter, Sunoco began fill operations on the Island [(1)].

Following the purchase of the Island, Sunoco installed a stone bulkhead between the mainland and the Island. Between 1941 and 1950, iron pyrites were deposited to the southwest of the Island. Between 1950 and 1960 spent filter clay, catalyst fines and rubble were deposited in this area. Some small areas were used to weather leaded tank bottoms. Figure 3 shows the location of the bulkhead and the extent of the fill [(1)].

In approximately 1960, a second bulkhead was installed. This area was filled between 1960 and 1965, predominantly with spent filter clay with some API separator sludge and demolition debris. The filter clays were used to de-wax certain refined lubricating oils. The spent clays were mixed with clean clays and placed and compacted on Phillips Island [(1)].

In 1965 and 1966 a clay dike was installed at the present extent of the Island. The dike location is shown in Figure 3. The dike is approximately 30 feet wide at its base and 20 feet wide at the crest. The dike is approximately 12 to 15 feet above the mean low water level. The face along the Delaware River is covered with 18 inches of rubble to prevent erosion. Spent filter clay was used to fill this area behind the dike [(1)].

The fill operations ceased in 1980. In 1985 and 1986, a portion of the site was brought up to grade using between 9,000 and 18,000 tons of fill consisting of 50 percent soil and 50 percent flyash. The ash was from the Delaware County Regional Authority (DELCORA) incinerator. Currently, the former fill area is covered with 1 to 3 feet of fill and soil from the construction of new stormwater tanks in 1992.

2.4 PREVIOUS INVESTIGATIONS AND REMEDIAL ACTIONS

In 1987, NUS, on behalf of the USEPA, performed a Preliminary Assessment (PA) of the Island[(2)]. The PA consisted of a site visit; environmental samples were not collected for laboratory analysis. The findings of the PA were:

- There are no home wells within a three-mile radius of the site
- There are no public water supply intakes within three miles of the site
- Land use immediately surrounding the site is industrial
- There are no critical environments within a three-mile radius of the site

In 1990, Sunoco retained ERM, Inc. to perform a subsurface investigation and screening study of the Island [(3,4)]. The ERM, Inc. screening report [(3)] concluded that capping the Island to prevent infiltration coupled with a containment remedy appeared to be the most feasible alternative.

The ERM subsurface investigation included 12 hand-auger borings, 3 soil borings, and 8 test pits[(4)]. A total of 22 soil samples were collected. The results indicated the presence of petroleum-related volatile organic compounds (VOCs), primarily benzene, toluene, ethylbenzene, and xylenes (BTEX), at concentrations generally below 1 milligram per kilogram (mg/kg). One soil sample contained ethylbenzene, toluene, and xylenes at concentrations of 11, 31 and 79 mg/kg, respectively. Detected semi-volatile organic compounds (SVOCs) were primarily polynuclear aromatic hydrocarbons (PAHs) at concentrations ranging from less than 1 to 100 mg/kg with one sample containing concentrations up to approximately 1,000 mg/kg. Two pesticides were detected, alpha-BHC and 4,4'-DDD; the concentrations were generally less than 0.5 mg/kg. One sample contained 4,4'-DDD at a concentration of 30 mg/kg. Fifteen metals were detected in the samples. The concentrations ranged between 0.6 mg/kg for mercury and 1,566 mg/kg for zinc. Total petroleum hydrocarbon (TPH) concentrations ranged from 17,300 mg/kg to 392,400 mg/kg.

In 1991 A.T. Kearney, Inc., on behalf of the USEPA, performed a Phase II Final RCRA Facility Assessment (RFA) of the Marcus Hook Refinery, including the Island [5]. In general, the RFA identified on the Island soil staining in the areas associated with surface features (e.g., the Training Area, roll-off staging area). The RFA did not identify immediate indications of impacts from the former fill area, specifically noting a lack of seeps along the river. The RFA suggested a subsurface investigation, as the former fill area is unlined.

In 1994, Sunoco submitted to the Pennsylvania Department of Environmental Resources (PADER) a Comprehensive Remedial Plan (CRP) for the Marcus Hook refinery. The CRP was modified in May 1995 to address PADER comments [6]. Relative to Phillips Island, the CRP Addendum included verifying the occurrence of LNAPL.

In 1995, Sunoco retained Groundwater & Environmental Services, Inc. (GES) to assess groundwater along the perimeter of the refinery [7,8]. The GES investigations included installing monitoring wells, 10 soil borings, and monitoring liquid levels in the borings and wells. The borings and wells were completed in fill and waste at a depth of approximately 30 feet; soil and groundwater samples were not collected. The GES investigation results indicated the presence of LNAPL at thickness between 0.34 and 14.03 feet. The liquid level monitoring did not indicate an apparent influence from the tidal cycles in the Delaware River. The liquid levels measured in the wells in the waste were anomalous relative to each other and precluded groundwater gradient interpretation [8]. GES further concluded there is little hydraulic communication between groundwater in the former fill area and the Delaware River [8].

In 1996, Sunoco submitted to the DEP a CRP for Phillips Island [9]. The plan for the Island specified LNAPL removal every two weeks via vacuum truck and installation of a LNAPL recovery pump in one well. The DEP approved the plan in 1996 with the condition that additional investigation of the impact of LNAPL on the river must be performed [10]. In the third quarter 1996 report, Sunoco responded that at all tidal levels, no seeps of LNAPL were observed along the perimeter of the Island [11].

Since 1995, Sunoco has monitored groundwater quality in the refinery perimeter wells on an annual basis in accordance with the CRP. One of the wells is located on Phillips Island, well

MW-118. This well originally contained 3 feet of LNAPL. The analytical results for well MW-118 indicate the historical presence of benzene (not detected to 140 micrograms per liter (ug/l)), ethylbenzene (not detected to 2 ug/l) and bis (2-ethylhexyl) phthalate (not detected to 10 ug/l). In the 1999 CRP sample from MW-118, no analytes were detected above the detection limit (10 ug/l) [12].

Sunoco continues to operate under the CRP. Status reports are submitted to the DEP on a quarterly basis. The LNAPL is removed every two weeks by vacuum truck and transported to the oil recovery system in the refinery.

2.5 PLANNED SITE REDEVELOPMENT

Sunoco and FPL Energy Marcus Hook, L.P. (FPLE) are negotiating the construction of a 750 megawatt gas-fired co-generation facility on the Phillips Island portion of the Sunoco Marcus Hook refinery (Figure 4).

The co-generation plant will use natural gas and refinery gas as a fuel source. This will reduce the number of boilers in use at the refinery and reduce the overall nitrogen oxide (NOx) and sulfur oxide (SOx) emissions. The plant will also boost the power available to the local electricity grid.

To address potential exposures to constituents of concern at the site, the co-generation plant will be designed with several components that will eliminate potential exposure routes. These include a vapor control system beneath all buildings that will be occupied by workers and the ground surface will be covered with either gravel or asphalt which will remove the potential for worker and ecological receptor direct contact with surface soil or vapors emanating from the subsurface.

A major component of the plant design includes stormwater control and re-use. Stormwater will be collected by overland flow and subsurface drains and channeled to the plant cooling towers and will substantially minimize the potential for infiltration while minimizing the use of potable water for non-contact cooling.

2.6 CONCEPTUAL SITE MODEL

The conceptual model for the site, based on the information from the background investigation is as follows:

1. The physical characteristics of the site include a clay berm along the Delaware River; fill materials consisting of process wastes such as filter clay (composed of bentonite clay) and

leaded sludge; rubble; demolition debris; and general refuse. The berm is covered with concrete riprap to prevent erosion.

2. The site is covered with a layer of soil and gravel.

3. The waste and fill materials contain petroleum-related compounds.

4. Compounds expected in site soil include volatile organic compounds (VOCs), polynuclear aromatic hydrocarbons (PAHs) and metals. Compounds suspected to be present include PCBs and pesticides.

5. LNAPL is present in wells completed within the waste material in the former fill area.

6. Groundwater occurs in the natural sediments underlying the site.

7. The hydrology of the site is complicated.

8. Groundwater quality data does not indicate significant quantities of dissolved compounds.

9. The filter clay has a high moisture content. Wells screened in the filter clay tend to act as sumps and accumulate soil moisture and LNAPL from the surrounding filter clay.

10. The low permeability of the filter clay and the berm has isolated the waste and fill from the surrounding environment.

2.7 ENVIRONMENTAL SETTING

The Phillips Island site is located in the southwest section of the Sunoco Marcus Hook refinery. The Island is approximately 21.1 acres resembling a small peninsula. The surface is generally flat with small topographic features and a raised area to the south that slopes steeply to the Delaware River. The slope is covered with concrete riprap to prevent erosion and the slope is terraced for an access road that surrounds the southern perimeter of the Island.

Historically, waste including filter clay was placed in the former fill area; fill was placed over other areas of the Island. The current edge of the former fill area consists of a clay berm covered with concrete riprap. The surface of the former fill area is covered with soil and gravel. Areas currently associated with refinery operations are covered with a concrete slab or gravel.

On the western face of the former fill area berm, near the high water line, seeps of petroleum are present. The seeps have impacted the rocks, stones, and soil of the adjacent shoreline. The area of seeps is limited to an approximately 150 feet section of the over 2,000 feet of shoreline of Phillips Island. The seeps appear to be associated with discrete layers of material slightly coarser than the clay berm. Minor areas of stressed vegetation (approximately 3 to 10 feet wide and less than a foot thick) and staining was observed at these seeps. The rocks, stones and soil on the tidal flats in the seep area are stained with petroleum from the seeps.

Another seep is located on the western face of the former fill area, approximately 10 feet down from the face and approximately 12 feet above the river water line. The seep encompasses an area of stressed vegetation of approximately 10 feet by 10 feet. Other than the seep, no other areas of stressed vegetation were observed near this area. The area is equipped with an oil recovery system that periodically pumps the oil into a storage tank. The oil is removed from the tank on an as-needed basis.

containerized at the well head in 55-gallon drums that were later pumped to the refinery wastewater treatment system.

The elevation (ground, inner casing and outer casing) and location of monitoring wells MW-137 through MW-146 were surveyed on March 7, 2000 by James M. Stewart, Inc. of Philadelphia, Pennsylvania and referenced to the same refinery horizontal and vertical datum used by Site-Blauvelt.

At the time of installation, the wells were numbered sequentially from MW-1 through MW-11. Since then, the wells have been incorporated into the Sunoco well network and were re-numbered MW-137 through MW-146. In this report, the wells are referred to by their new designation. The laboratory data reports in the appendices will bear the original well designations. URS/Dames & Moore has provided notations on each laboratory data sheet corresponding to the revised well designation to facilitate cross-referencing.

3.4 HYDRAULIC MEASUREMENTS

3.4.1 Slug Testing

Slug testing was performed on six of the site wells (MW-138, MW-140, MW-141, MW-143, MW-145, and MW-146) on February 28 through March 7, 2000. The slug testing was performed to estimate the hydraulic conductivity of the native materials underlying the fill at the Island. The slug testing was performed by the inserting (falling head test) and removing (rising head test) of a PVC slug into the water column to displace the water in the well. A pressure transducer that was placed in the well before the start of slug testing and connected to a data logger monitored the test. Each step of the slug test, insertion and removal, was monitored separately and the data was recovered from the logger prior to the start of each step. The data from the removal step (rising head) was analyzed by the updated Bouwer and Rice method (Bouwer, 1989). The data was analyzed using the Aqtesolv® for Windows software package. The results of the slug testing are discussed in Section 4.2.4. The graphical results of the slug testing are presented in Appendix E.

3.4.2 Tidal Influence Monitoring

Tidal influence monitoring was performed on six of the site wells (MW-138, MW-140, MW-141, MW-143, MW-145, and MW-146) on February 25 through March 2, 2000. The monitoring was performed using a pressure transducer and data logger that was programmed to record the water level every 15 minutes. Data was collected for a minimum of 48 hours at each of the wells and was used to graph water level versus time to determine if there is a tidal influence on the groundwater. The graphs were compared to tidal tables prepared by the National Oceanic and

Atmospheric Administration (NOAA) to access if variations in the water table correlate to the tides. The results of the tidal influence monitoring are discussed in Section 4.2.3. The tidal influence graphs are presented in Appendix F.

3.5 GROUNDWATER SAMPLING

Groundwater samples were collected from pre-existing wells MW-40 and MW-118 and newly installed wells MW-137 through MW-146 on February 23 – 25, 2000. A second round of samples were collected on April 27, 2000 from wells MW-40, MW-113 through MW-118, MW-121, and MW-137 through MW-146.

The wells were sampled using the low-flow (minimal drawdown) technique in accordance with the DEP groundwater monitoring guidance and USEPA low-flow purge technique. Low-flow purging has the advantage of curtailing mixing between the overlying stagnant casing water and water within the screened interval. In some monitoring wells, the low hydraulic conductivity of the material (slow recharge) resulted in drawdown even at low-flow (less than 0.1 gpm) withdrawal rates. The groundwater sampling event was scheduled to be completed in one day; however the slow recharge of the wells and the large sample volume required for the analysis of the requested parameters resulted in sampling over a three-day period. Because of drawdown even at low-flow rates, the second round of groundwater sampling was performed by purging three well volumes or to dry. Purge water was containerized at the well head in 55-gallons drums that were later discharged to the refinery wastewater treatment system. ||?

Prior to purging the wells and collecting groundwater samples, URS/Dames & Moore measured the depth to groundwater and determined the presence or absence of LNAPL. If LNAPL was present, a groundwater sample was collected from that well during the second (not first) round of groundwater sampling. If LNAPL was not detected, URS/Dames & Moore installed a submersible pump in the well to a depth of approximately half way up the screened interval, and purged a minimal amount of water from the well. While purging, URS/Dames & Moore personnel periodically measured temperature, pH, specific conductivity, oxidation-reduction potential, turbidity, and dissolved oxygen until all readings stabilized (+/- 10 percent). Once stabilized, groundwater samples were collected from the pump outflow, in accordance with the low-flow technique, from each well except MW-143 that was sampled using a dedicated disposable bailer and nylon rope. (Monitoring well MW-143 was pumped dry by low-flow purging due to very poor recharge. The groundwater sample was collected by bailer after the well recovered sufficient water to sample.) Each sample was poured into the laboratory-prepared bottleware (dissolved metals were field filtered by URS/Dames & Moore personnel), packaged in iced coolers, and submitted to Raytheon under proper chain of custody protocol. The first round of samples was analyzed for the parameters listed in Table 1. The second round of samples was analyzed for VOCs, SVOCs and dissolved metals. The results of the groundwater sample analyses are discussed in Section 5.1.

3.6 LNAPL SAMPLING

On February 8, 2000, a grab sample of LNAPL was collected from open borehole B-PH10. The sample was submitted to Raytheon Laboratories for specific gravity and PCB analysis.

On February 22-23, 2000, URS/Dames & Moore measured LNAPL thickness and collected a LNAPL sample from wells MW-113, MW-115, MW-116, MW-119, MW-121, and MW-121A using a dedicated, disposable bailer and nylon rope. LNAPL thickness ranged from 0.03 feet (MW-114) to 6.35 feet (MW-119), as shown in Figure 6 and listed on Table 3. Monitoring wells MW-114 and MW-117 contained an insufficient thickness of LNAPL (0.03 feet and 0.10 feet, respectively) for sample collection. Each sample was poured into the laboratory-prepared bottleware, packaged in coolers, and submitted to Raytheon Laboratories under proper chain of custody protocol, for specific gravity and PCB analyses.

On April 10, 2000, a sample of the LNAPL was collected from MW-116 for analysis of VOCs, SVOCs, and petroleum fingerprint analysis. On May 22, 2000, three samples were collected for analysis of petroleum fingerprint. LNAPL samples were collected from the west shore sump and a seep at the high tide water level beneath the west shore sump. A soil sample was collected from the shoreline beneath the sampled seep. The samples were submitted to Raytheon Laboratories under proper chain of custody protocol. The results of the LNAPL sample analyses are discussed in Section 5.4.

3.7 GEOTECHNICAL SAMPLING

Geotechnical sampling was performed at the site on March 13, 2000. The purpose of the sampling was to collect samples of the fill material and the possible bulkhead materials at the site to determine their hydrogeologic characteristics. The geotechnical-boring program involved the installation of 5 soil borings. The borings were drilled with a hollow-stem auger drill rig. The borings were advanced by driving a two-foot long split spoon sampler with a standard ASTM 140-pound hammer in general accordance with ASTM standard 1586. The blow counts required to advance the sampler were recorded over six inch intervals during installation. The soils collected in the sampler were field classified by the onsite URS/Dames & Moore geologist by the using the USCS. Boring logs for the geotechnical borings are presented in Appendix C. The locations of the geotechnical borings are presented on Figure 5.

An undisturbed sample was collected from each boring for geotechnical analysis by the Shelby tube sampling method in general accordance with ASTM method 1587. The Shelby tube method involves pushing a three-foot long thin walled steel tube using the hydraulic system of the drill rig. The sample was sealed inside the tube with wax to hold the sample in place and the ends of the sampler were capped. The samples were stored in an upright position until delivery to the URS Geotechnical Laboratory in Totowa, New Jersey. The samples were analyzed for triaxial permeability, oil and water content, and grain size. The results of the geotechnical analyses are discussed in Section 4.2.4 and are presented in Appendix G.

3.8 DRAWDOWN TESTING

URS/Dames & Moore performed a drawdown test on wells MW-115, MW-116, and MW-117 to assess the potential long-term drawdown. The test included installing three piezometers, each located approximately 5 to 6 feet from each of the wells being tested. On March 24, 2000, the 2-inch diameter piezometers were installed by hollow stem auger to a depth of 30 feet. The piezometers were constructed with 25 feet of screen. Boring logs for the piezometers are presented in Appendix C.

The drawdown test was performed on MW-115, MW-116, and MW-117 on March 29 through April 4, 2000. The test was monitored by data loggers connected to pressure transducers placed in the newly installed piezometers to monitor the water level. The wells were pumped with a small submersible pump until the well was completely dewatered. The wells were pumped intermittently over a three-day period to maintain the dewatering; the very low hydraulic conductivity at the site did not allow the wells to be pumped constantly. The fluids generated by pumping were containerized in 55-gallon DOT approved drums pending disposal by Sunoco employees. The results of the drawdown testing are discussed in Section 4.2.4. The drawdown test results are presented in Appendix H.

4.0 PHYSICAL CHARACTERISTICS

This section discusses the physical features and characteristics of the site. Section 4.1 and 4.2 present the geology and hydrogeology of the site, respectively.

4.1 GEOLOGY

According to geologic mapping performed by the Pennsylvania Geological Survey (1981), the site is underlain by the Quaternary-age Trenton Gravel Formation. The Trenton Gravel Formation is described as gray or reddish brown gravelly sand with cross-bedded sand and clay-silt beds. Bedrock was not encountered during the soil-boring program but based on the Pennsylvania geologic survey map, the bedrock is believed to be anorthosite, a plagioclase feldspar (anorthite)-rich gabbro and associated contact metamorphic rocks. Geotechnical borings completed at Phillips Island by Black & Veatch in February 2000 as part of the design of the co-generation plant encountered anorthosite bedrock at depths of 35 to 80 feet indicating the bedrock surface depth is highly variable across the site, but generally slopes down to the east.

To assist in evaluating geologic conditions at the site, URS/Dames & Moore reviewed the logs of borings installed at the site. The boring logs are included in Appendix C. The locations of the borings are shown on Figure 5. Three distinct geologic units (fill, waste, and sediments) are present in the subsurface at the site to a depth of 50 feet bgs and are described below. Figure 7 presents geologic cross sections for the site.

4.1.1 Fill Material

The uppermost unit present at the site is composed primarily of fill consisting of a brown silt or clay with aggregate, brick fragments, and concrete rubble and soil from the 1992 construction of the new stormwater tanks. The fill unit generally extends from the ground surface to an approximate depth of 5 to 18 feet bgs and is laterally contiguous across the site.

Borings drilled in the areas of the clay berms encountered dark gray clay from approximately 3 feet bgs to the top of the native sediments. The clay appeared compact and dense.

4.1.2 Waste Material

The materials encountered within the former fill area of the site consist primarily of dense gray clay from refinery filtering operations at the site. Other waste materials included construction and demolition debris, glass, gravel, wood, and metal fragments. The waste has discrete and discontinuous zones with high soil moisture and LNAPL content. The boring logs indicate a distinct variability in moisture content with depth, alternating in some borings from moist to wet to moist conditions. The wells installed in the waste material in 1995 by GES act as accumulation sumps for the soil moisture and LNAPL. The volumes of liquids in each well are dependent on the depth and the zone penetrated and results in apparent liquid elevations that are variable within short distances. Three borings that were targeted for completion in native sediments were terminated before native sediments were encountered due to LNAPL rapidly filling the boreholes.

The waste materials unit generally extends from the base of the fill material unit to an approximate depth of 42 feet bgs. The waste is laterally discontinuous to the west of the former fill area. The fill unit occurs at the same stratigraphic elevations as the waste in the eastern portion of the site. The waste thickness in the eastern portion of the site is approximately 10 feet. The waste is also discontinuous to the north of the former fill area.

4.1.3 Native Unconsolidated Materials

The native materials encountered at the site consisted primarily of gray silty clay. Some areas of the site further away from the Delaware River also contained beds of orange brown sand and gravel. The materials present near the river are consistent with Delaware River fluvial deposits. The materials present further away from the river are consistent with the Trenton Gravel Formation.

Figure 8 is a contour map showing the elevation of the top of the natural soil horizon. From the contours it appears that the original shoreline was oriented east to west in the approximate center of the site. The contours also indicate a possible channel oriented approximately north/south in the vicinity of Blueball Avenue. The slope on the southern end of this channel flattens out indicating a small delta deposit. The sediments encountered in these areas are consistent with this interpretation. The sediments at location MW-140 and B-PH7 contain varying amounts of silty clay and sand and gravel (likely channel deposits in a tidal stream). At GP-PH4 and MW-142 the sediments are mostly clayey silt with lesser amounts of sand and gravel.

4.2 HYDROGEOLOGY

URS/Dames & Moore installed ten groundwater-monitoring wells (MW-137 through MW-146) at the site in February 2000. The locations of these monitoring wells are shown on Figure 5. Construction details for all of the monitoring wells at the site are presented in Appendix C.

The existing monitoring wells (MW-40, MW-114 through MW-119, MW-121, and MW-121A) and the newly installed monitoring wells (MW-137 through MW-146) were surveyed on March 7, 2000 to determine their locations and elevations by James M. Stewart, Inc., a Pennsylvania Licensed Surveyor. Groundwater elevations in the monitoring wells were measured on February 23, 2000, March 15, 2000 and April 26, 2000. Groundwater elevation measurements are summarized in Table 3. The elevations from February 23 were not used for interpreting groundwater flow, as the water levels had not stabilized from well development the week before. Groundwater elevation contour maps are presented as Figure 9a (March 15, 2000) and Figure 9b (April 26, 2000).

4.2.1 Groundwater Elevations

The groundwater measurements from previously installed wells MW-113 through MW-119, MW-121, and MW-121A, which are screened within the fill and waste, were not used to generate the contour map from March 15, 2000 since the water levels measured within the filter clay-rich waste appear to be anomalous. Groundwater in these wells occurs at erratic depths that do not correlate with each other or the newly installed wells. The water levels do not appear to be connected to the indigenous sediments underlying the waste. The previously installed wells were screened from 5 feet below ground surface to 30 feet below ground surface and they are completed within the fill and waste materials at the site. The wells act as sumps for the soil moisture. Thus, the amount of water accumulated in the wells is in direct correlation to the penetrated zones.

The groundwater level elevations from the monitoring wells in the indigenous sediments were above the top of the sediment horizon indicating that groundwater occurs under semi-confined conditions within the unconsolidated materials above bedrock.

LNAPL was detected in monitoring wells MW-113, MW-114, MW-115, MW-116, MW-117, MW-119, MW-121, and MW-121A during groundwater level measurements that were obtained on February 22 and March 15, 2000. The groundwater elevations for the monitoring wells containing LNAPL presented on Table 3 were corrected for the presence of LNAPL based on the specific gravity of the LNAPL sample collected from each well (Appendix K). The LNAPL thickness in monitoring wells on March 15 ranged from 0.07 feet in MW-114 to 6.35 feet in MW-119.

4.2.2 LNAPL Seeps

LNAPL also occurs at seeps along the western bank of the island. One seep is located approximately 10 feet down the slope and the LNAPL is recovered using an LNAPL recovery system.

On the western face of the former fill area berm, near the high water line, seeps of petroleum are present. The seeps have impacted the rocks, stones, and soil of the adjacent shoreline. The area of seeps is limited to an approximately 150 feet section of the over 2,000 feet of shoreline of Phillips Island (Figure 13). The seeps appear to be associated with discrete layers of material slightly coarser than the clay berm. Minor areas of stressed vegetation (approximately 3 to 10 feet wide and less than a foot thick) and staining was observed at these seeps. The rocks, stones and soil on the tidal flats beneath the seeps are stained with petroleum from the seeps.

4.2.3 Groundwater Flow

The groundwater level measurements from the monitoring wells at the site indicate that groundwater flow beneath the site is to the south toward the Delaware River. Such a groundwater flow direction is consistent with the hydrogeology of the area. The groundwater elevation at MW-146 (near the river) is higher than the surrounding area and likely is due to a mounding effect caused by the bulkhead along the Delaware River. Based on the groundwater level measurements obtained on March 15, 2000, the estimated average hydraulic gradient at the site is 0.0225.

Tidal influence monitoring was conducted on wells MW-138, MW-140, MW-141, MW-144, MW-145, and MW-146. Tidal influence was observed in wells MW-138, MW-140, MW-145, and MW-146. The water table variance due to tides ranged from 0.05 feet in MW-140 to 0.29 feet in MW-146. In general, there appears to be a greater tidal influence in the wells screened in coarser grained materials. Tidal influence in MW-141 and MW-144 was not apparent and may have been masked due to water level recovery from sampling.

4.2.4 Hydraulic Properties

Hydraulic Conductivity

Slug testing was performed on wells MW-138, MW-140, MW-141, MW-144, MW-145, and MW-146. The estimated hydraulic conductivity varies widely, as expected from the variations in the native materials at the site. The slug tests performed within the silty clay ranged from 0.01103 ft/day in MW-141 to 0.03478 ft/day in MW-144 with an average hydraulic conductivity of 0.02291 ft/day. The slug tests performed in wells screened in sediments containing silty clay and sand and gravel ranged from 0.5634 ft/day in MW-146 to 12.83 ft/day in MW-140 with an average hydraulic conductivity of 6.87 ft/day. The hydraulic conductivity values estimated for the materials at the site are consistent with published values for those materials [(13)].

The results of the geotechnical analyses were utilized to calculate the horizontal and vertical hydraulic conductivity of the fill and waste materials at the site. The horizontal hydraulic conductivities ranged from 4.9×10^{-8} cm/sec (GT-5) to 3.1×10^{-5} cm/sec (GT-4). The vertical hydraulic conductivities ranged from 2.9×10^{-8} cm/sec (GT-1) to 2.9 x 10-7 cm/sec (GT-5). The conductivity of the waste filter clay (GT-4 and GT-5) and the clay berms (GT-1 and GT-3) were very similar. The hydraulic conductivity analysis is presented in Appendix G.

Drawdown and Yield Calculations

Shelby tube samples of waste material were collected at four locations for permeability testing. The laboratory measured both vertical and horizontal permeability. The values are listed in Appendix G. The transmissivity (T) at each location was calculated from the equation:

$T = Kb$

Where K = horizontal permeability
b = saturated thickness

The estimated yield at each location was obtained by the equation:

$T = 2000\ C_s$

Where T = transmissivity in gal/day/ft
C_s = specific capacity in gal/min/ft
Yield = Cs x saturated thickness in feet

From the Theis equation, the radius of influence at each location was calculated. The conservative assumptions used were:

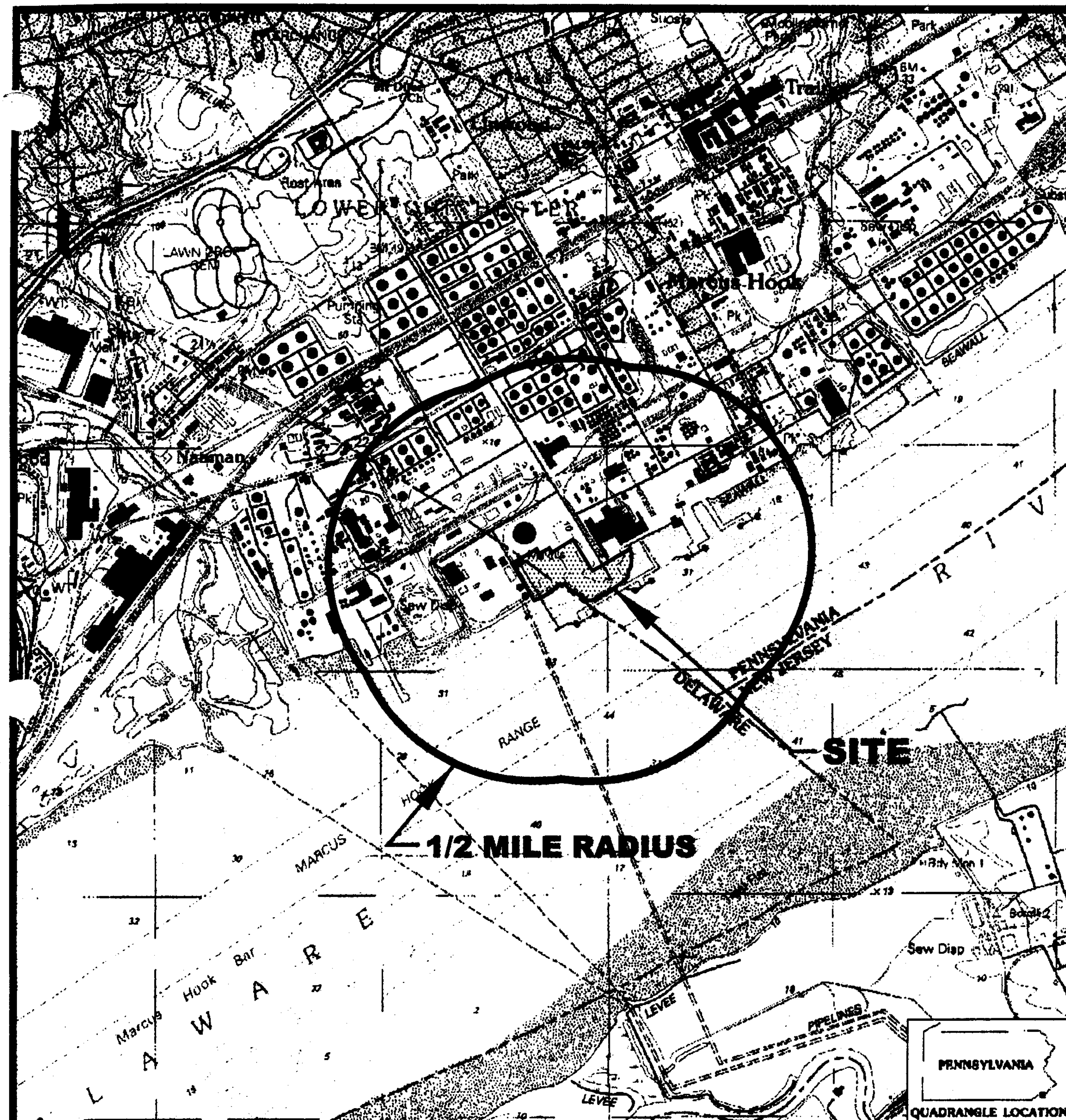
- Pumping for 10 days (assumes a significant precipitation event an average of every 10 days)
- Specific yield = 0.05 (S)
- Drawdown at radius of influence = 0.01 foot

The results are:

Location	Saturated Thickness (feet)	Max. Pumping Rate (gpm) for 10 days	T (gpd/ft)	S	Radius of Influence (feet)
GT-1 (MW-141)	8	0.00014	0.034	0.05	0.15
GT-3 (MW-143)	30	0.003	0.19	0.05	8.7
GT-4 (MW-145)	18	0.1	11.4	0.05	62
GT-5 (B-PH-7)	30	0.000016	0.0318	0.05	2.0

Drawdown Testing

The results of the drawdown test were inconclusive. The water levels in the piezometers were constantly rising during the period of the testing, which masked the drawdown from the pumping of the nearby well. The cause of the water level recovery may be a delayed response to the bi-weekly evacuation of the LNAPL recovery wells or the water levels were still recovering to static levels following disturbance during the piezometer installation. The very low hydraulic conductivity at the site results in a very slow recovery rate. Based on these data and observations during the drawdown test, it will take greater than three days to establish the zone of influence around a recovery well. Once that zone is established, though, it can be maintained at very low pumping rates.



0 1000 2000 3000 FEET

GRAPHIC SCALE

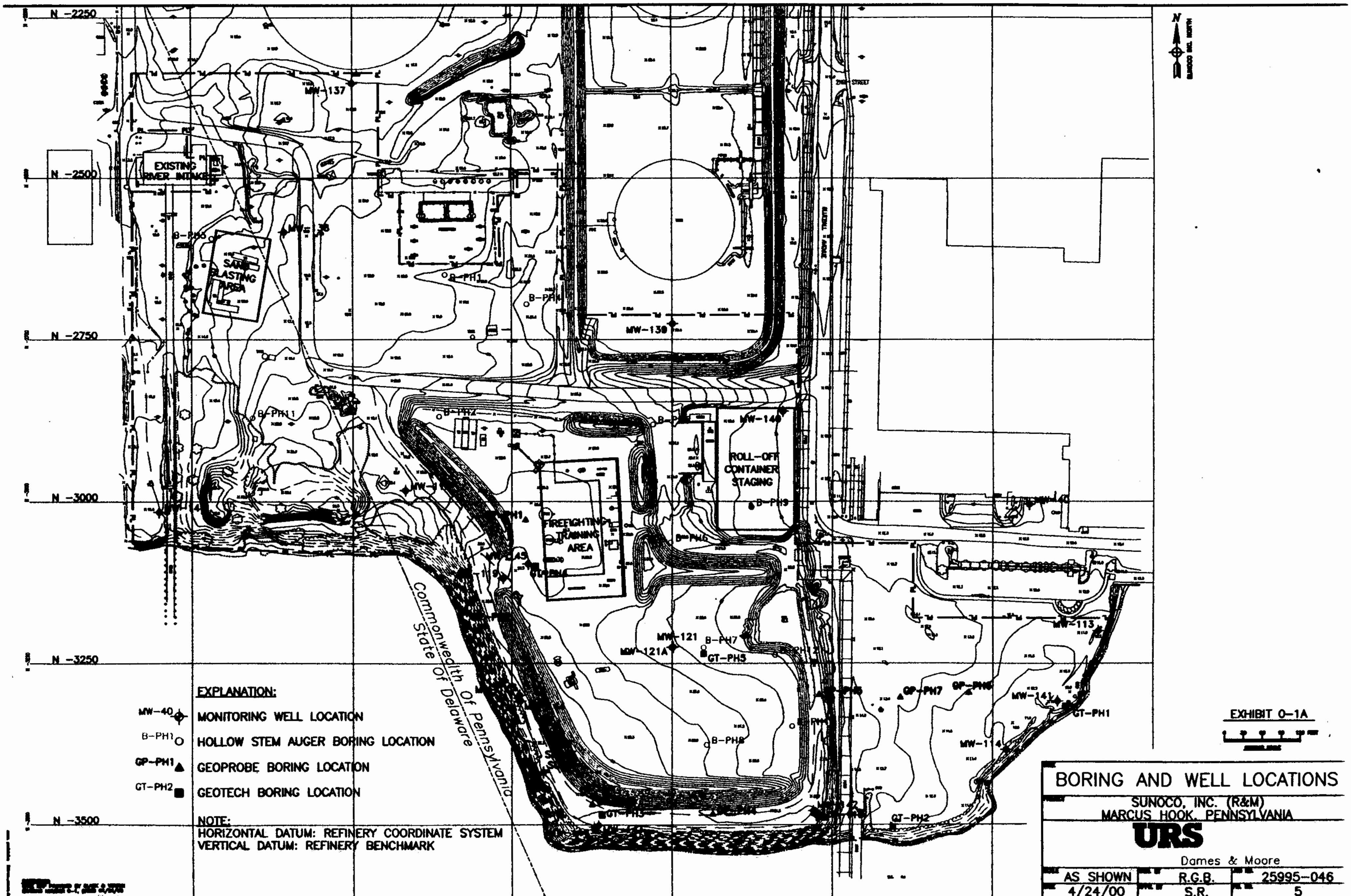
CONTOUR INTERVAL = 10 FEET

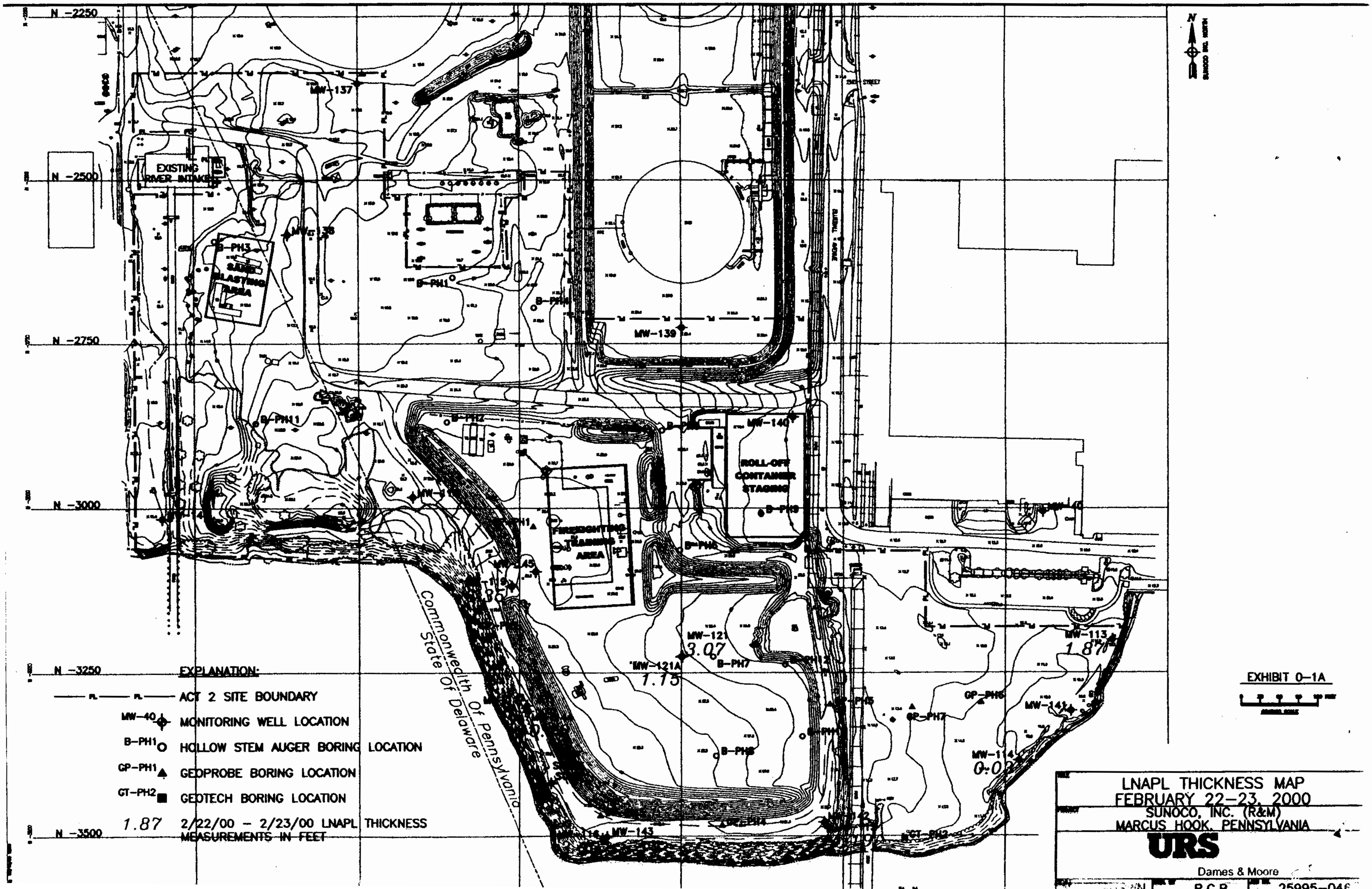
REFERENCE:
A PORTION OF USGS 7.5 MINUTE TOPOGRAPHIC MAP; MARCUS HOOK QUADRANGLE, PENNSYLVANIA; 1993.

05/31/00 09:27

(5) 00316-0

TITLE					
SITE VICINITY MAP					
PROJECT: SUNOCO, INC. (R&M) MARCUS HOOK, PENNSYLVANIA					
URS Dames & Moore					
SCALE	AS SHOWN	DWN. BY	R.G.B.	JOB NO.	25995-047
DATE	5/31/00	APPR. BY	T.R.B.	FIG. NO.	1


N -2250
N -2500
N -2750
N -3000
N -3250
N -3500
MW-137
EXISTING RIVER INTAKE
B-PH3
SAND BLASTING AREA
B-PH1
B-PH4
MW-139
B-PH11
B-PH2
MW-140
ROLL-OFF CONTAINER STAGING
B-PH9
FIREFIGHTING TRAINING AREA
B-PH6
MW-121
MW-121A
B-PH7
GT-PH5
B-PH8
GP-PH7
MW-141
GT-PH1
MW-114
MW-113
GT-PH2
Commonwealth Of Pennsylvania
State Of Delaware
EXPLANATION:
MW-40 MONITORING WELL LOCATION
B-PH1 HOLLOW STEM AUGER BORING LOCATION
GP-PH1 GEOPROBE BORING LOCATION
GT-PH2 GEOTECH BORING LOCATION
NOTE:
HORIZONTAL DATUM: REFINERY COORDINATE SYSTEM
VERTICAL DATUM: REFINERY BENCHMARK
EXHIBIT O-1A
BORING AND WELL LOCATIONS
SUNOCO, INC. (R&M)
MARCUS HOOK, PENNSYLVANIA
URS
Dames & Moore
AS SHOWN
4/24/00
R.G.B.
S.R.
25995-046
5



N -2250
N -2500
N -2750
N -3000
N -3250
N -3500
EXISTING RIVER INTAKE
MW-137
MW-138
B-PH3
SAND BLASTING AREA
B-PH1
B-PH4
MW-139
B-PH11
B-PH2
MW-140
ROLL-OFF CONTAINER STAGING
B-PH9
FIREFIGHTING TRAINING AREA
MW-145
B-PH6
MW-121
3.07
MW-121A
1.15
B-PH7
B-PH8
MW-143
GP-PH6
GP-PH7
MW-141
MW-113
1.87
MW-114
0.02
GT-PH2
Commonwealth Of Pennsylvania
State Of Delaware
EXHIBIT 0-1A
EXPLANATION:
ACT 2 SITE BOUNDARY
MW-40 MONITORING WELL LOCATION
B-PH1 HOLLOW STEM AUGER BORING LOCATION
GP-PH1 GEOPROBE BORING LOCATION
GT-PH2 GEOTECH BORING LOCATION
1.87 2/22/00 - 2/23/00 LNAPL THICKNESS MEASUREMENTS IN FEET
LNAPL THICKNESS MAP
FEBRUARY 22-23, 2000
SUNOCO, INC. (R&M)
MARCUS HOOK, PENNSYLVANIA
URS
Dames & Moore
R.C.B.
25995-046